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Hansen, Kamilla Marie Speht; Spiliotopoulou, Aikaterini; Cheema, Waqas Akram; Andersen, Henrik Rasmus

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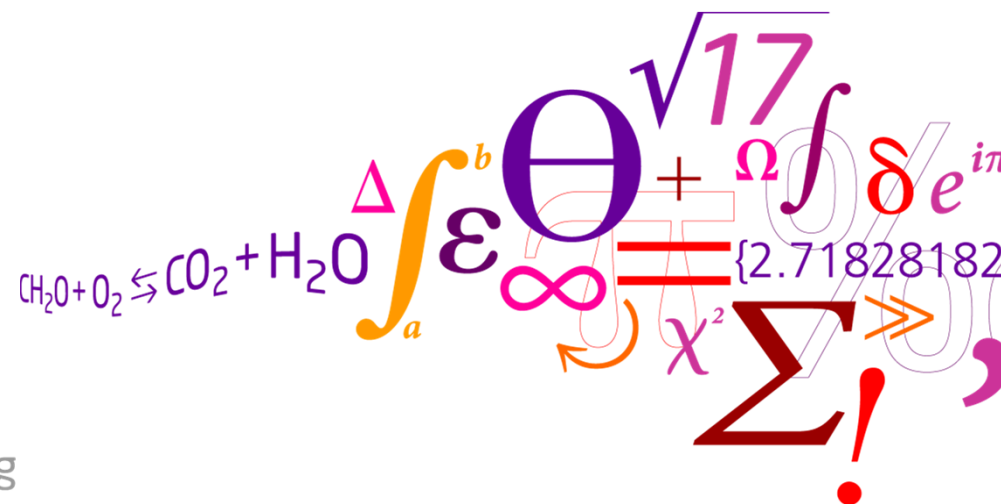
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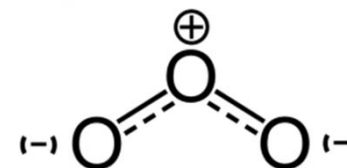
Laboratory studies on the effect of ozonation on THM formation in swimming pool water

K.M.S. Hansen, A. Spiliotopoulou, W.A. Cheema, H.R. Andersen

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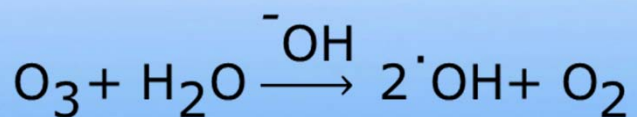
Ozone chemistry



$t_{1/2}, 20\text{ }^{\circ}\text{C} = 3\text{ days}$

$t_{1/2}, 20\text{ }^{\circ}\text{C} = 20\text{ min}$

Increased pH



Contaminants

High reactivity:

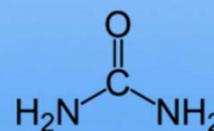


double bond

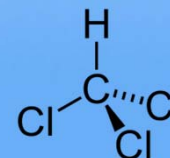
Low reactivity:



Urea



Organo-chlorine



Ozone chemistry

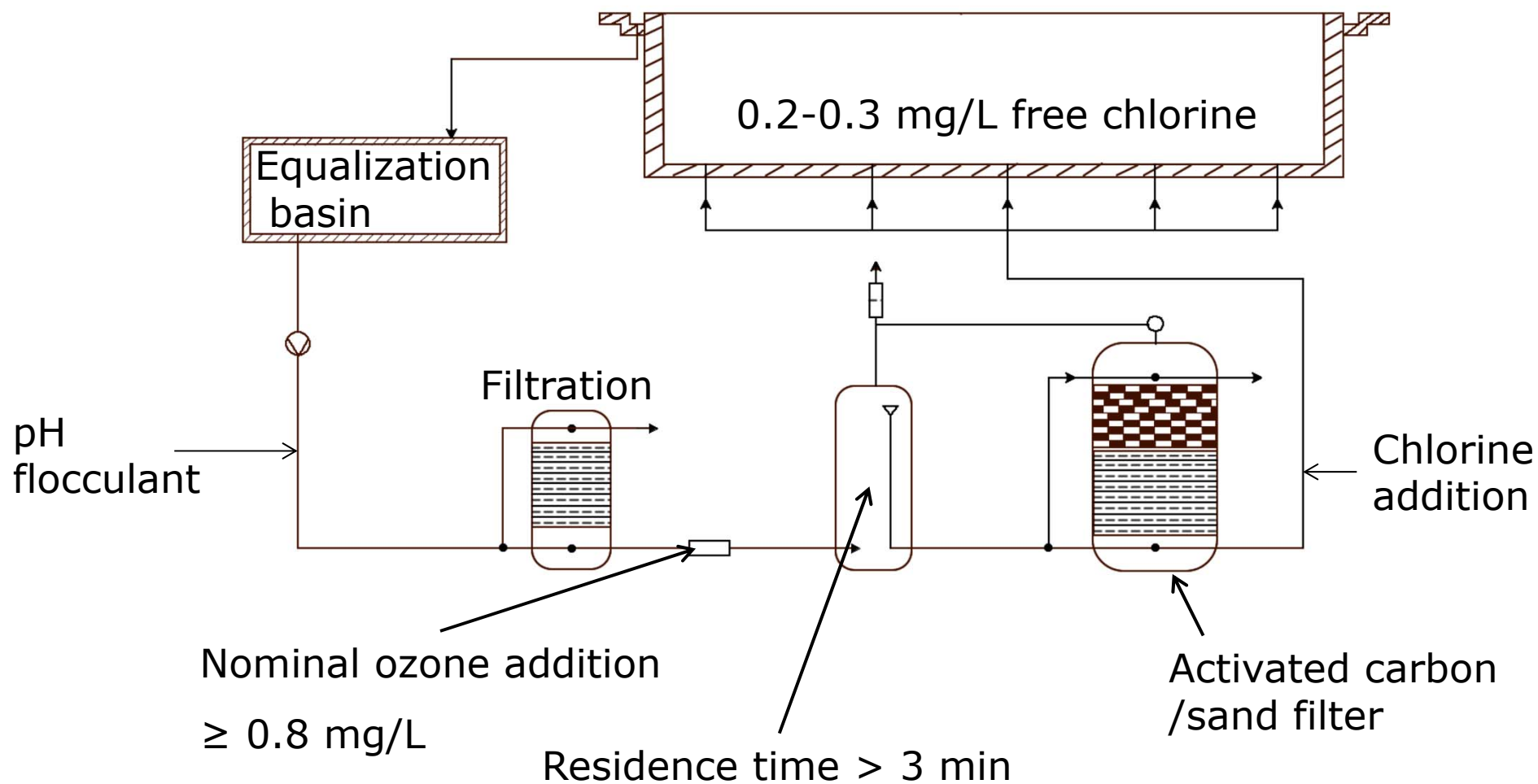
I. Organic matter reactive with ozone

- Direct oxidation by ozone
- Fast consumption of ozone
- Decrease chlorine reactivity of pollutants
- Low ozone life time → no reaction with bromide

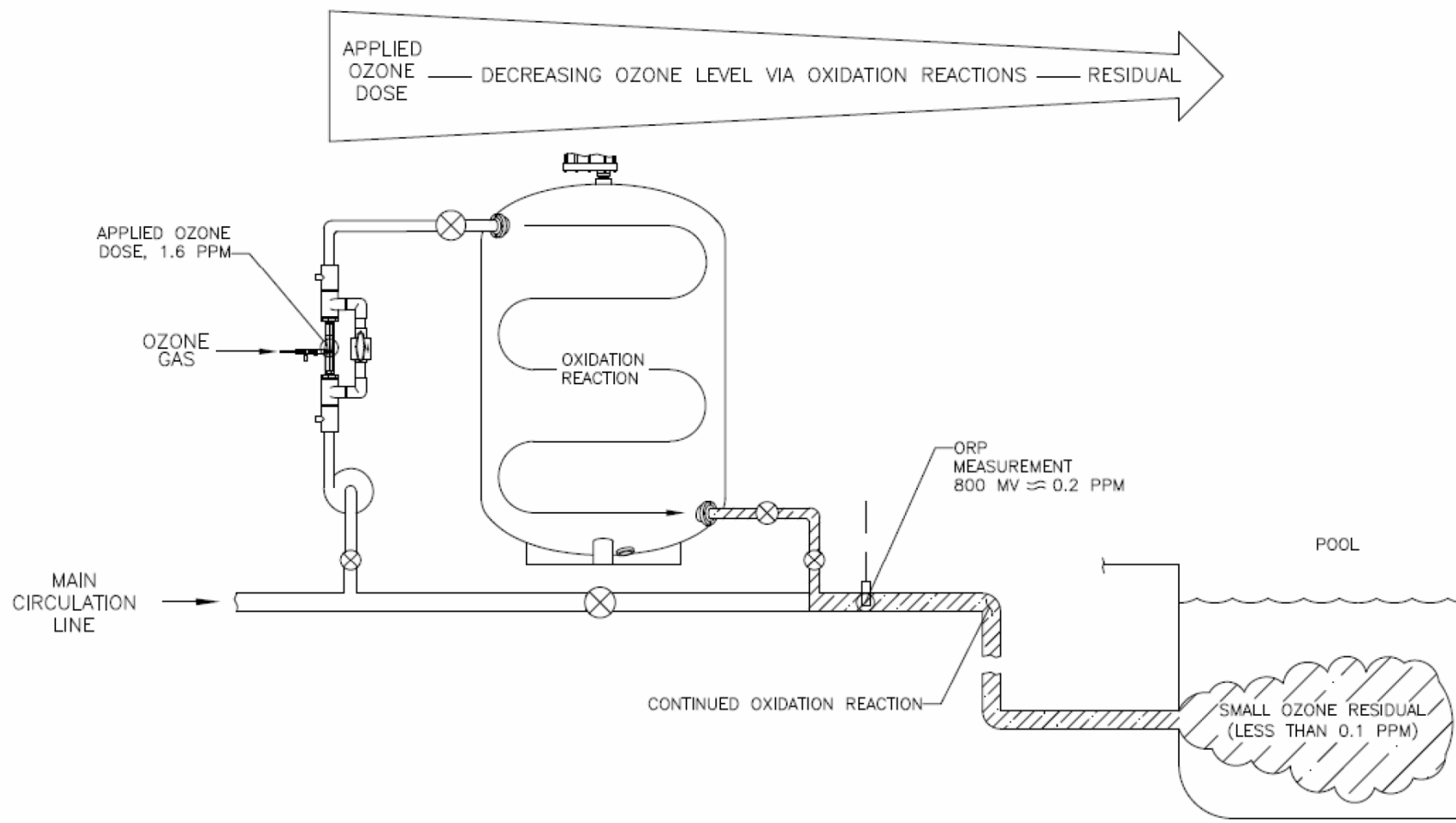
II. Organic matter not reactive with ozone

- Slow consumption of ozone
- Ozone converts to hydroxyl radicals with time
- Radical attack of inactive carbon → increased chlorine reactivity
- Long ozone life time → oxidation of bromide to bromate

Systems: DIN (German standard)



Systems: Slip-stream (USA)



Our aim

Optimizing ozone treatment

- Contact time
- Required ozone dose to minimize chlorination DBPs

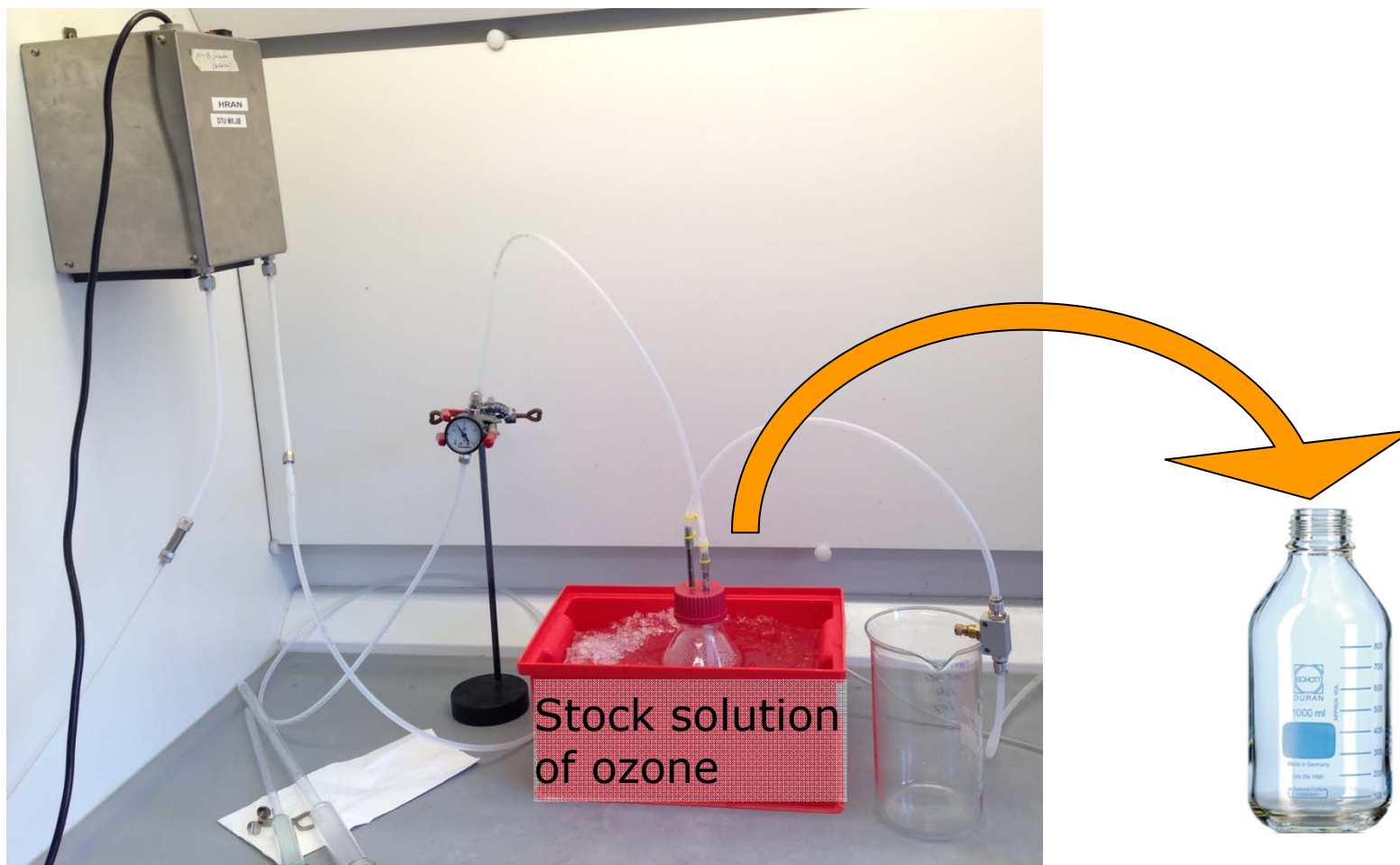
Ozone kinetics not well described in swimming pools

- Effects of pH
- Effects of organic, repeated ozonation

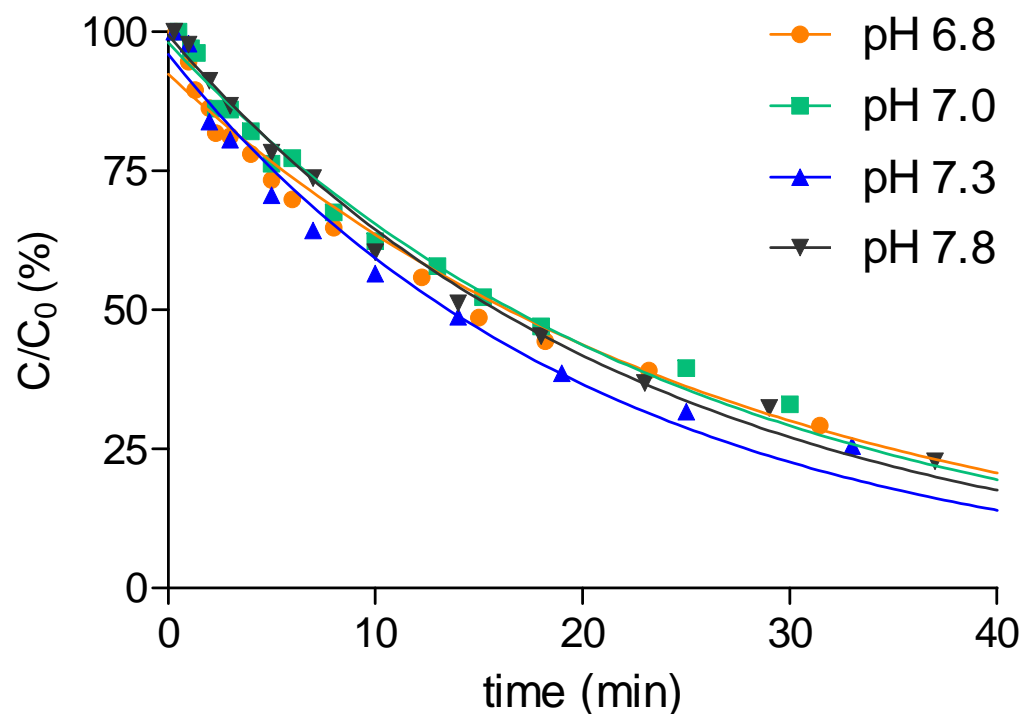
Effect of ozonation on DBP formation

- Pool water
- Filling water
- Fresh pollutants

Lab-scale experiments

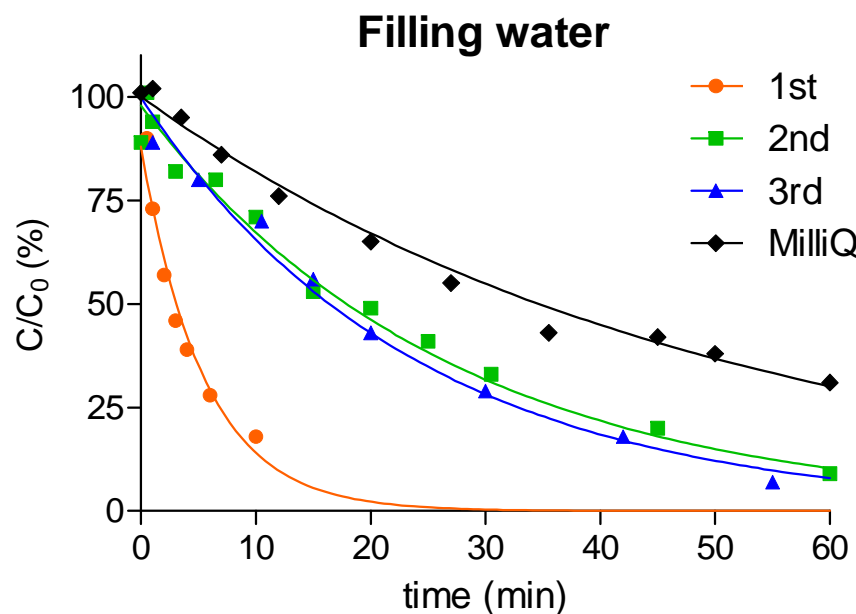


Effect of pH on ozone lifetime

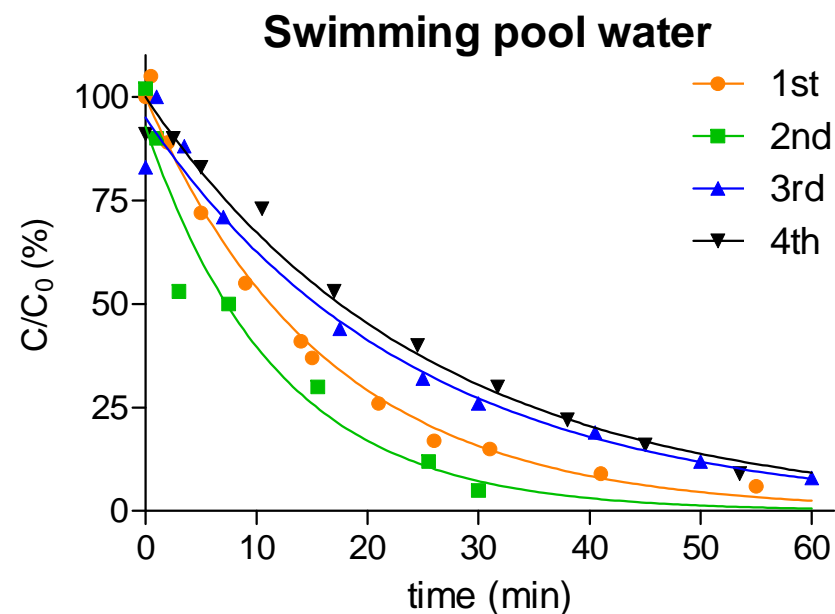


- Very little difference in the pH range swimming pools are operated

Repeated ozonation – ozone lifetime



- Fast removal of 1st ozone dose → ozone reactive material
- 2nd and 3rd → no ozone reactive material



- Little difference → no ozone reactive material in the water

Chlorination of the ozonated samples



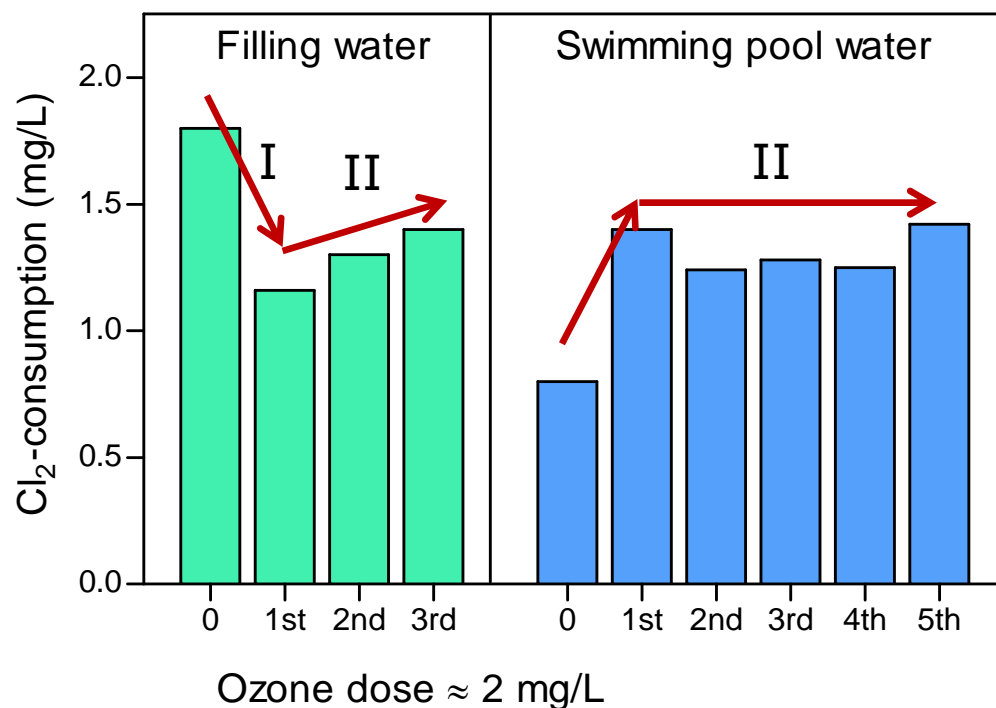
Chlorine: 24 h at 25 °C

Chlorine residual +

Purge & trap – GC/MS



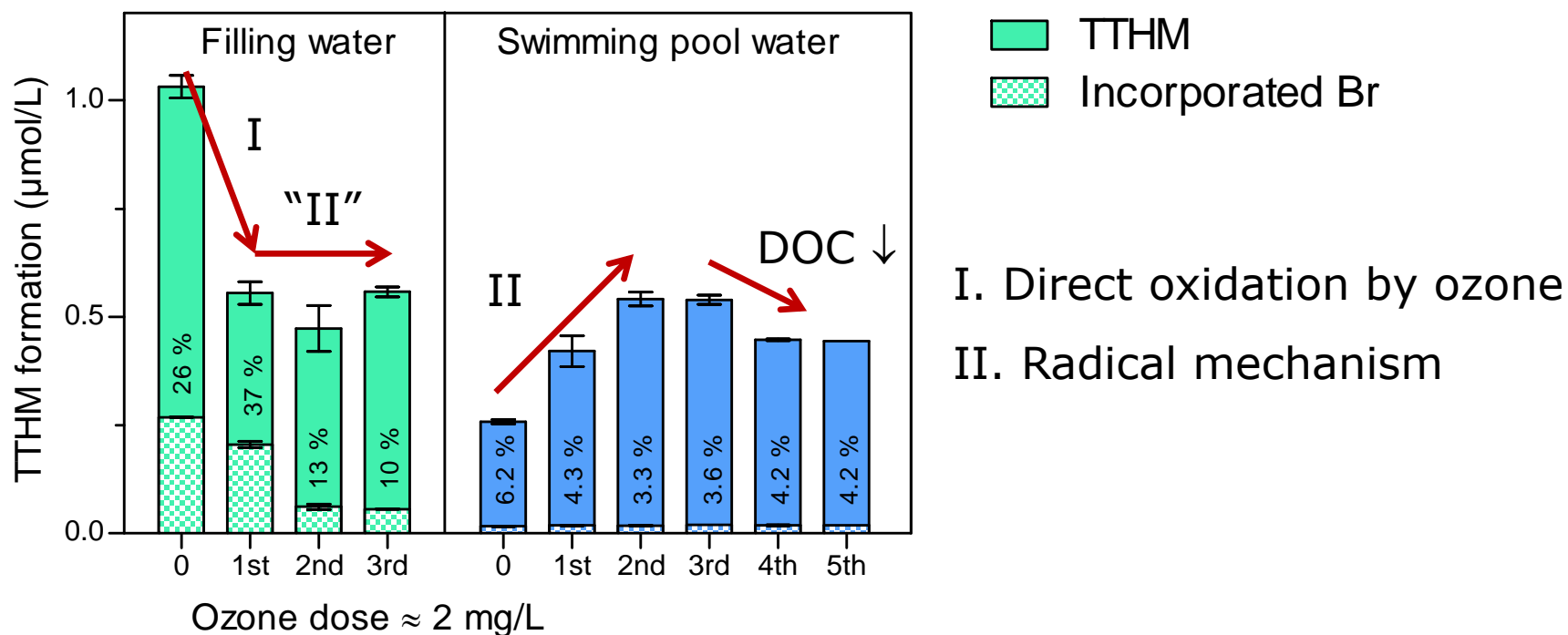
Chlorine consumption



- I. Direct oxidation by ozone
- II. Radical mechanism

- Different chlorine consumption for tap water and swimming pool water

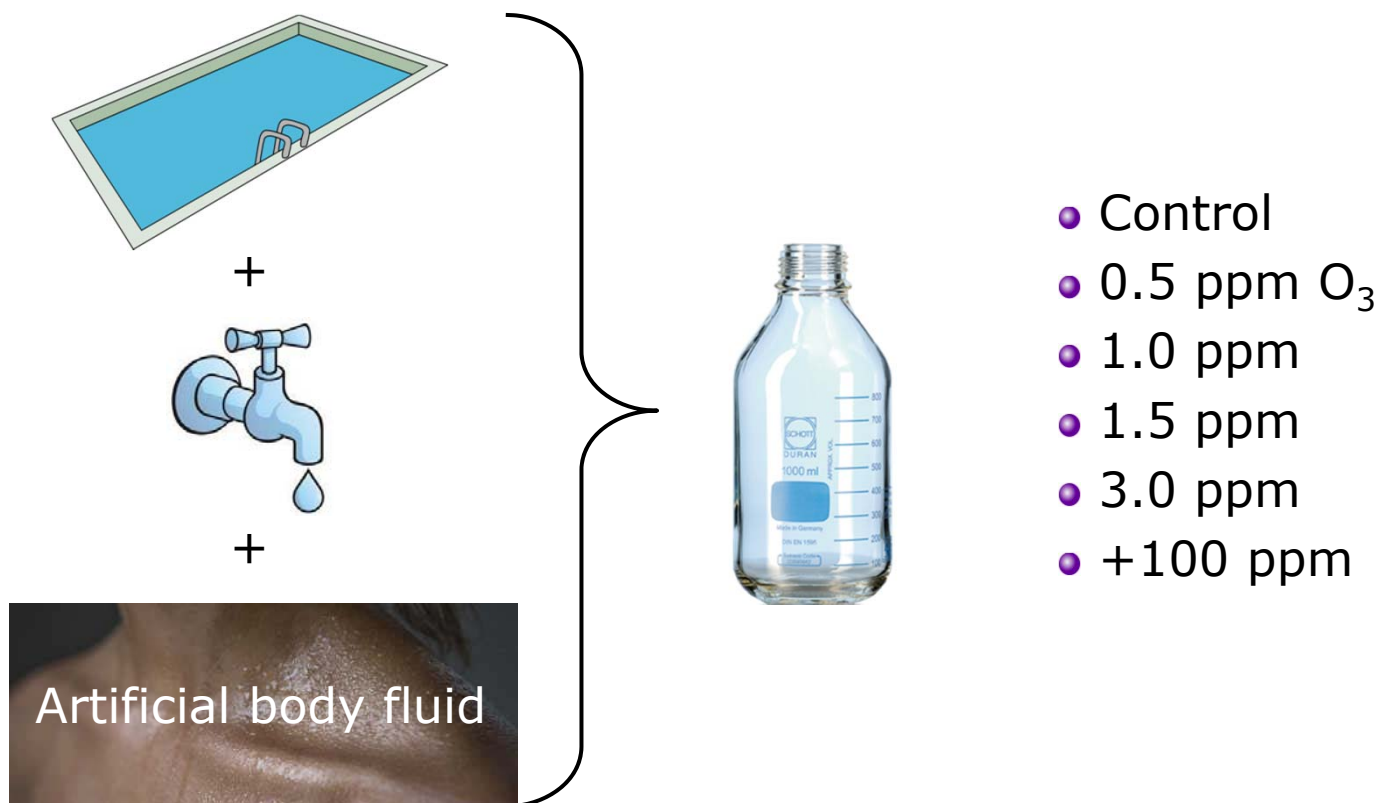
Formation of total trihalomethane



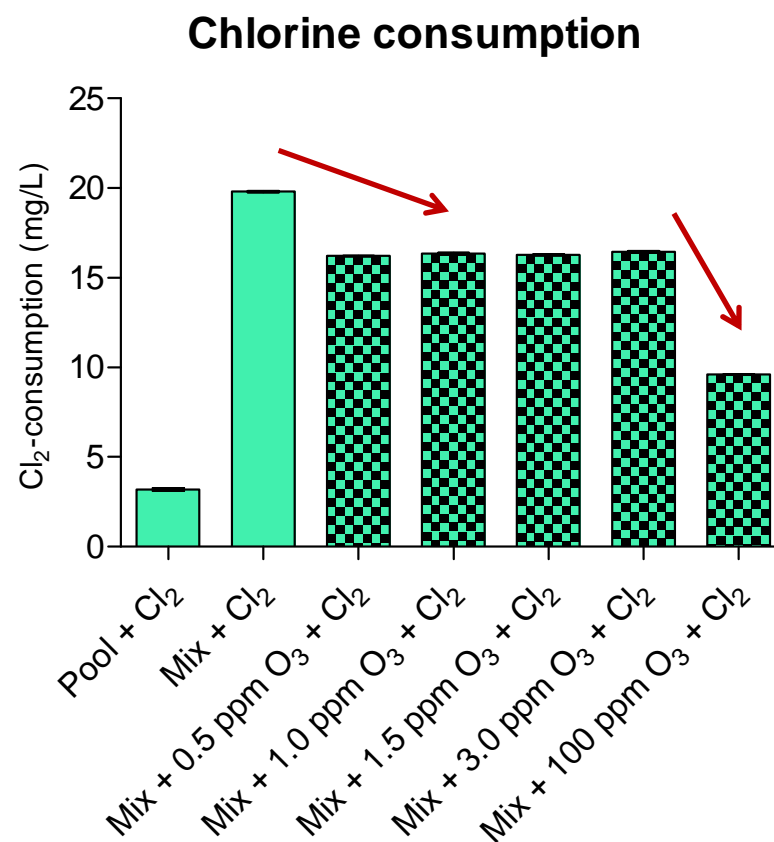
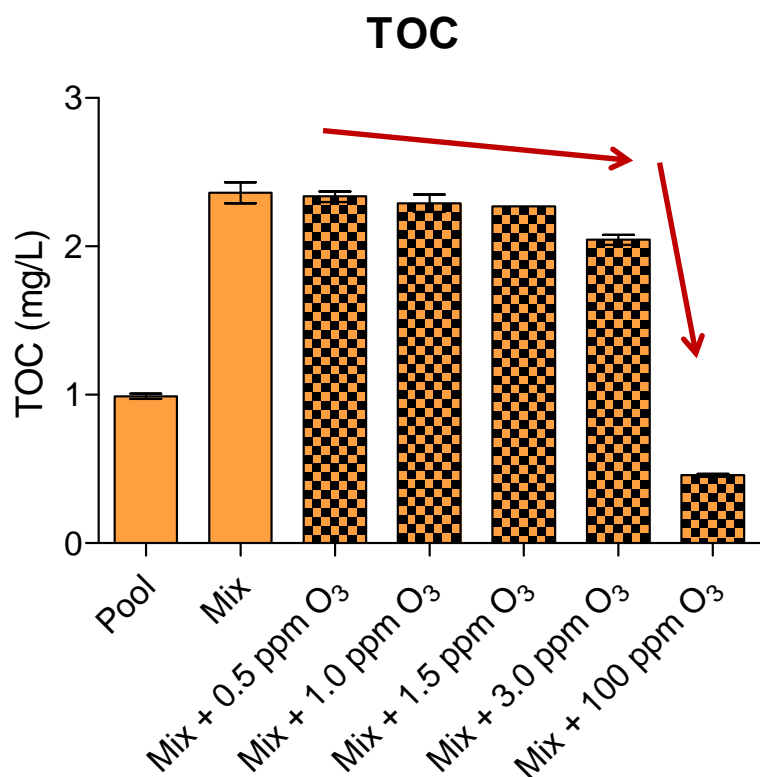
- Ozonation of filling water \rightarrow decreased THM
- Ozonation of swimming pool water \rightarrow increased THM

Fresh pollutants

Why do not we see an decrease in THM formation in pool water?

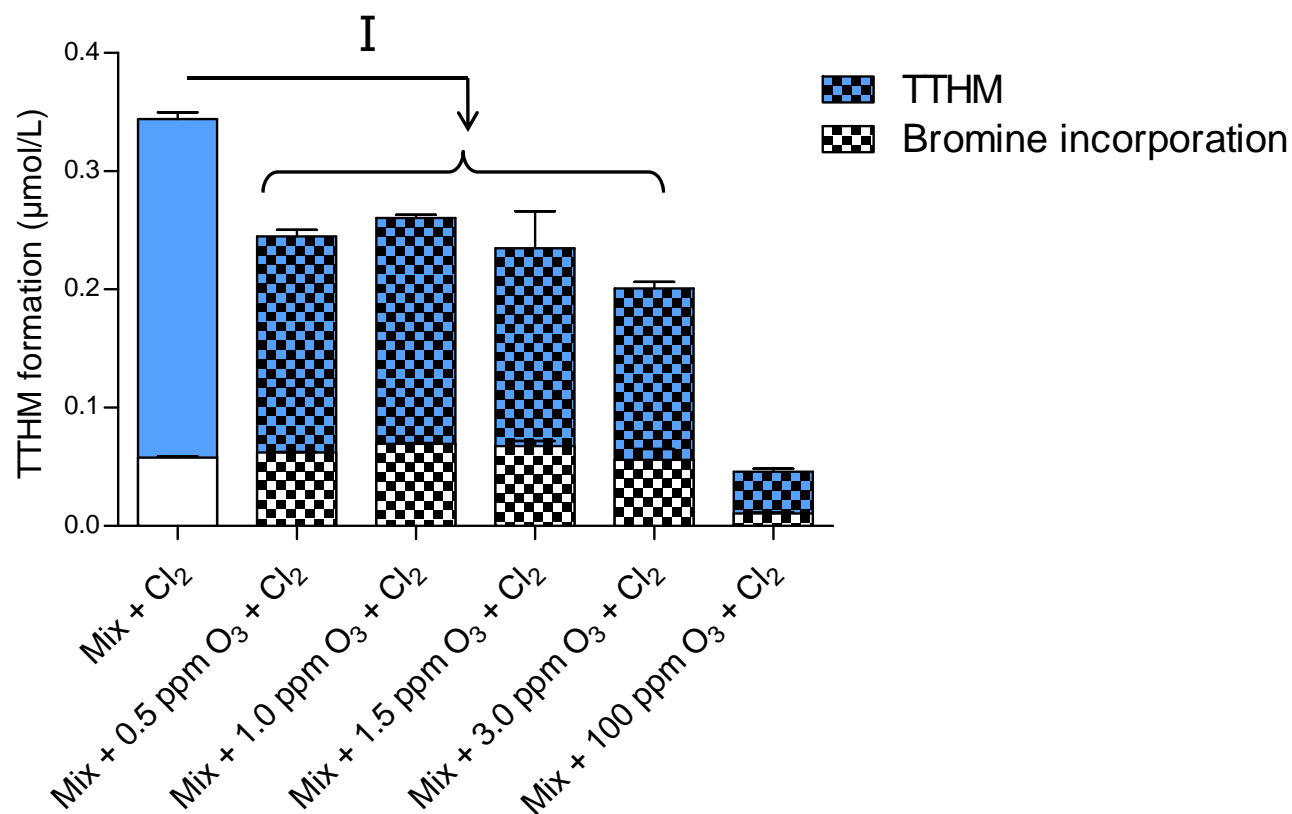


Total organic carbon (TOC) and chlorine consumption



- Ozonation decrease TOC and decreased chlorine consumption

TTHM formation



- Fresh pollutant direct ozone reaction → short ozone life time → no decrease in formation of brominated THM

Conclusions

Kinetic possible

- pH minimal effect
- TOC (ozone reactive vs non-reactive)

Chlorinated pool water

- Reaction via hydroxyl radical, making the organic material more reactive and increased THM formation.

Presence of fresh pollutants

- Direct oxidation by ozone → decreased THM formation
- Still need some more information on ozone dose required

Thanks for your attention

See you at the next pool conference with
results from ozonation of full scale system

